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Motivation, Limiting Principles, Household Characteristics, Urban Structure, and Residential Choices

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ABSTRACT

This paper reviews some theoretical, empirical, and practical drawbacks of urban problem approaches based on analogies to physical processes. It suggests an abstraction of man, as the basic building unit of the urban system, retaining motivation characteristics of people that seem to underlie human behavior in an urban setting. It states some of the basic principles that appear to underlie and limit this behavior and outlines the consequences on urban growth and structure that follow from these principles and characteristics. It also presents some empirical work that indicates the approach is useful to clarify structural relationships in the system, and to study the effects of some individual, community, and institutional goals on the development of urban forms. The approach seems useful to identify system interfaces where coordinated contributions from several disciplines are needed. The approach apparently can yield a surprisingly large amount of sensible information from samples as small as 17-50 households.

Introduction and Background

This paper overviews some urban problem approaches that have scientific content, it expresses some views about their merits and faults, and suggests ways which may be useful to overcome some of these faults. It also presents some empirical results which support these suggestions.

The semi-scientific approaches to the study of urban problems to which we refer here originated mainly in large scale studies for transportation-land

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use planning, community renewal programming, and subsequently, in what could be called social renewal programs. We also refer, where pertinent, to limited selections from the large amount of scientific work, such as socio-medical research, mental health research, and others, incident to many urban problems which are now being incorporated and coordinated into large-scale efforts.

The scientific content of urban research work can be established by the application of three criteria:

- Existence of basic theoretical postulates
- Extent of penetration of rigorous logic and mathematics in the definition of concepts, statement of relationships and deduction of consequences from the basic theoretical postulates
- Degree of empirical justification of the basic postulates and of deducted consequences through replicable experiments.

Urban problems embrace biological, social, psychological, economical, and technological aspects which are susceptible to scientific treatment. These aspects do not exhaust all essential considerations but are such that, if missing in the application, their absence will fault the technical-artistic creation of a functionally sound and aesthetically fulfilled ordering which should be the finished urban form.

Three main theories are in use for major urban transportation-land use and renewal studies: social physics, opportunity, and land use economic theories. Since economic theory is mixed into all, we restrict our summary discussion to the first two.

Social physics theory, derived from analogies between some urban and some macrocosmic physical processes, is founded in the postulate that certain aggregate behaviors of people are analogous to the collective motion of charged physical particles in a field of force and obey similar regulating principles. This theory underlies the so-called gravity and potential formulas of urban zone interaction, of urban travel between origins and destinations, of location of new retail establishments, and other mathematical statements of urban growth and development.[1-4,6] The most commonly used in transportation-land use studies has been Voorhees Gravity formula.[7-10] Lowry[11] has used social physics theory in mathematical modeling of urban growth.[12] Other investigators have extended the gravity model[13,14] and proposed formulae derived from statistical mechanics,[15] electrical network and gravitational theory,[16-18] but their efforts have not yet found use in any major urban studies.

The main weakness of social physics theory is its analogical basis. It lacks fundamental principles of its own corresponding to the principles and assumptions of physics such as conservation of energy, homogeneity and

conservation of field of force, which underlie the physical gravity and potential formulae. Social physics formulae are in the end regression equations which describe observable statistical regularities but have little material for theory building or explanatory value in terms of a scientific behavior theory. Most of the empirical work associated with it consist of parameter estimation to bring calculated results into agreement with empirical observation; no serious attempts seem to have been made to validate the implied behavior theory.

The opportunity theory is an explicit theory of behavior grounded on an extension of Zipf's principle of least effort, which is a behavior analogue of Mapertuis' principle of least action in physics.[5] Zipf's principle postulates that people prefer the behavior that requires the least expenditure of effort to reach their goal. The extension to opportunity theory, made by Schneider and first applied in the Chicago Area Transportation Study[19,20] states that urban travelers prefer for each purpose the destination nearest to their points of origin, and that potential destinations are considered successively with a constant probability of acceptance at increasing distances from the origin. Different population groups have different acceptance probabilities. The mathematical formulae follow from these basic postulates by logical derivation. The theory has the awkward implication that a person starting towards work, for instance, considers as potential trip terminals all suitable destinations enclosed within a circle centered at origin and drawn with radius equal to the distance traveled. Tests of the derived formulae have been aimed mainly at estimation of acceptance probability parameters that yield calculated numbers of trips close to counts of between-point trips.

Both opportunity and gravity models are considered acceptable for overall transportation network planning although there are problems in their application to small areas, to areas crossed by physical barriers, and to forecasting growth in presently undeveloped areas. It is often necessary to introduce more or less arbitrary correction factors in the equations for some origin-destination pairs, but not for others; sometimes different equations are needed for situations which are intuitively similar; estimation errors vary widely.[21]

The need to forecast future transportation requirements leads to the need for prediction of urban growth, of area population increases, and of changes in distribution and intensity of industrial and commercial activities.[22] The need to include these processes in the development of mathematical models of transportation demands brought forth their extreme interdependence. This provided a natural direction for expansion of the theories of urban travel to theories of urban systems, for their application to the study of urban growth and decay, and for application to

community renewal planning. Lowry's effort[11] is perhaps the first attempt to use the systems approach in the study of urban growth.

Although some concerted efforts to develop a general mathematically rigorous theory of systems have been in progress for some time,[23,24] urban systems approaches do not differ so far substantially in scientific content from the earlier work of the large scale transportation studies. More emphasis is given now to the simultaneity and interaction of urban demographic, socio-economic and technological processes, but significant progress has not been made in theory or experimental validation. Furthermore, the basic definitions of urban system and of the most commonly used expressions in "urban systems" talk, such as transportation system, environment, balanced systems, system goals, etc., remain unclear for application to the urban context. The definition of a system, as a collection of elements organized to achieve certain goals of the system in its environment, is clear when the system is an organism. Paraphrasing it: an urban transportation system, for example, should mean the collection of elements organized to achieve goals of the transportation system in its environment. But transportation is a service to help *urban residents* achieve goals that require transportation. These are goals of people, not of the system itself. The accepted systems definition leaves out side effects on what we could call quality of life and quality of human environment which are implicit in many people's goals.[25] This lack of clarity in the basic system concepts makes it difficult to distinguish, to understand, and to express the relationships between the design characteristics of the transportation system and the individual and community socio-economic goals it is supposed to serve.

The systems approach, despite these serious deficiencies in definitions and theory, has scored important achievements. The systems view of urban transportation and urban development planning has been extremely useful through the development of simulation models. Simulation models place in the hands of urban policy makers means to evaluate more objectively than ever before the plausible consequences of contemplated policies and to detect unsuspected effects before the policies are implemented. Furthermore, the development of these models needed special efforts to gather coherent data on the several urban processes, by itself an extremely important service. These efforts eventually led to the creation of data banks, increasingly important for planning and essential for emerging scientific work.[26]

Cost-benefit has been the primary criteria of the systems approach for comparative evaluation of alternative policies. This represents some improvement over earlier engineering-efficiency criteria used in the layout of highways and construction of other public service facilities. Cost-benefit,

cost minimization, gross revenue optimization, and other systems evaluation criteria are convenient measures easy to grasp and easy to use to compare alternatives. These measures are, however, unfortunately inadequate to evaluate policies and projects that have major social impact.[27] It is not surprising that with the increased familiarity of educated people with the methods of engineering and scientific measurement, skepticism, suspicious scrutiny, and outright emotional rejection, without benefit of sound judgment, have increased together with serious, well-founded opposition from some humanists, writers, journalists, and other intellectuals. The pervading use of monetary cost criteria, they argue, has resulted in larger industrial and commercial units that can feed only on the cost advantages possible with large scale operations. These eliminate most of the personal service relationships that usually developed between smaller groups of customers and their goods and service suppliers which could not remain competitive with the large operators.

Economies of scale are possible through mechanization and elimination and substitution of some jobs with subsequent displacements of people from their traditional residences and places of work. The consequence has been the fragmentation of communities into eventually disconnected groups and, not rarely, into large masses of disconnected individuals, some of them forced into inactivity and kept alive on public charity. Historical city landmarks have given way to new buildings more efficient in rentable space per ground space used. The result has been the break of the emerging future with its roots in the past, disregard for natural and aesthetic values, pollution, ugliness, loss of informal and symbolic functions of urban spaces, detrimental social imprinting in children and adults, social illnesses, and criminality.[28-34]

There exists sufficient scientific evidence of the plasticity of the brain to qualitative and quantitative environmental experiences, pre- and post-natally, far above what could be expected as responses to hygiene, nutrition and average care, to substantiate several of these views.[35-39] Others seem scientifically testable although few, if any, have been sufficiently investigated to establish solidly their factual existency and relationships.

Some of these objections and their implicit goals are in part reducible to measures of neighborhood characteristics that apparently contribute to the establishment of informal but essential functions. Street grid (size of blocks), diversity of activities, segregation of motor and pedestrian traffic, access to playgrounds, movement experience, are essentially details of local design and of their integration into the overall city form. It is thus fairly evident that engineering the city has inescapable implications of engineering, to some extent, people and society.

A scientific approach to urban planning problems should therefore be firmly grounded on a theory that does not ignore these key factors either because of convenience or of necessity. The acceptability and fruitfulness of the scientific study of urban life and its full development for individuals and communities hinges on the proper inclusion and treatment of these effects. The nature of these goals precludes their inclusion in social physics approaches or in the ones based on existing urban behavior theories.

Theoretical Basis

It seems evident that a first point of attack should be the substitution, at the central point of the behavior theory, of some simple abstraction of man's essential characteristics in place of the characteristics of inert particles and of acceptable versions of natural principles that control animal and human behavior, in place of the analogies to the physical laws of the kinetics and interaction of particles. Such an approach would immediately dispel some of the definitional difficulties in the systems view: urban life is an exclusive human phenomenon; evidently the central system is homo so-called sapiens, without him there are no problems. Since homo is a product of evolution and adaptation, the systems environment is clearly defined: man's physical, biological, individual, and social environments. The essential parts of the system are thus man's physical, biological, mental, and cultural components. The sensible goals of the system are then the full and balanced growth and development of these components in an urban context. The first task would then be to find a suitable abstract simplification of the human characteristics that underlie behavior. Such a simplification should retain the essential features of life, perception, valuations, inborn behavioral imprints, learning, rational and irrational choice. From the work of biologists, neuro-psychologists and other scientists, we can compose some suitably simplified version of the organic mechanisms involved.[40–43] From the work of psychologists and psychiatrists, we can extract some essential features of the basic psychological functions that underlie observable behavior and of their development through life.[44–47] The selection used here is one of many possible and has no claim of merit other than it seems to square off sufficiently well with the facts of which I am aware and to provide an adequate starting point. My arguments for this selection are given in reference 48.

The fundamental point is that man's behavior is motivated. By this, I mean that it involves arousal and execution of a pattern of action. Arousal requires the existence of predisposing internal state and of a releasing clue which can come from immediate perception of a feature in the real environment or from a deductive or intuitive association of elements in the

organism's experience and internal representation of its external environment. The action patterns may be inborn, that is, genetically transmitted; learned, which could be by conscious training or through unconscious post-natal imprinting. Patterns of action can also be selected through a conscious evaluation of objectives and courses of action. The mechanism of arousal and release of action patterns is mediated by the reticular activating system, by the hypothalamus and thalamus and involve the cortex of the brain. For our purpose, we do not need much detail; it is sufficient to know that the arousal of some highly specific action patterns is associated with excitation states, chemical, electrical or sometimes simply by pressure on precise spots in the hypothalamus. For instance, the complex actions associated with eating, drinking, sex, aggression, flight can be evoked by artificial stimulation of precise regions of the midbrain.[49-51] Cessation of artificial stimuli at these points brings cessation of the behavior after satiation. Prolongation of the stimuli brings continuation of the behavior beyond satiation. In some experiments it has been shown that satiated rats stimulate themselves to create thirst, to drink more and repeat satiation.[50] We may therefore say that arousals to specific actions, which we could call "drives," are associated to specific excitation points, that satiation normally cancels the arousal and that this cancellation is pleasurable in itself.

For abstract representation of this mechanism, we thus need to associate specific positions of a map or other device representative of the motivational physiological mechanism to specific "drives" and to associate a quantum or a scale of excitation intensity to each of these positions. Furthermore, we need a representation of the process of satiation by which the excitation may be reduced to zero. We also have to make allowance for existency of inactive or latent drives, the sex drive in children for instance, whose activation, regulated by organic growth mechanisms, marks in time states of biological development.

All drives that can be ultimately traced to inborn behavior patterns have come to us through evolutionary development. That is, through selective action of the environment on the populations of ancestral organisms and through the existence in these populations of genetical capability to produce forms better adapted to changed environmental situations. Guts capable of digesting meat exist because meat is and was obtainable from the environment; spiders weave webs because there are spider food morsels of adequate size, mass, etc., flying around. An intimate relationship between the organism and its environment has always existed. We call this a relationship of "Complementarity."

Consider a place devoid of population of any kind, a tract on the moon say, and place an organism on it. If it is to survive its presence continually creates a field of needs for specific elements and conditions. These

conditions and elements must be present or obtainable within the energy reserves available to the organism. For short stays, like those of the astronauts, meeting the biological requirements may be sufficient. For longer periods, the list of essentials grow to include other needs: companionship, identity, long term mental and social needs.

The individual is not motivated exclusively by his own needs. The primitive hunter out to get food was not satisfied with the first squirrel bagged; he wanted food for his family, for his tribe, and also prize for his ego. Pride for the hunter's ego does not come from consumption alone, it is given by the gestures, words and regard from his fellow hunters. Because of these ancestral social impulses he makes the needs of others: family, tribe, nation, affiliations his own. We can call the total, the needs of his extended self. These needs are the results of drives that arose because of their species survival value and are as much a part of human nature as the need for food.[5 2]

The satisfaction of extended self drives requires groups of minimum size above certain critical levels. Every human adaptation implies a technology: a collection of procedures and artifacts used in the steady procurement of the elements and execution of the tasks needed to satisfy material needs. This technology must necessarily have always been commensurate with the size of the group, totality of tasks to perform, and with the kinds and quantities of material resources available. It should not be strange to find these sizes and relationships deeply imbedded in our emotional makeup.

The representation of the material and emotional drives of the extended self therefore has to include representation of a complex spectrum of socio and psycho-genic drives in addition to the needs generated by organic processes. This can be done by representing drives of aggregates of individuals by the aggregation, of the drives of their component individuals.

We can associate to each recognizable drive a pattern of positions in an n-tuple or drive vector. Ideally vector positions should represent recognizable midbrain locations whose excitation corresponds to the particular drive. This is not at this time entirely feasible but for our purpose the concept may suffice. We can conceptualize the excitation states by quanta at each position and drive intensity by the number of quanta at each position. We can call these quanta "charges" and assign to them a + or - sign. Satiation will thus be represented by algebraic addition of the negative of the excitation state. We can call this pattern the "Complement" of the excitation state. We can also assume the existence of an object in the environment with properties that associate it to a specific drive. We can call this object a "charge carrier." The organism is thus represented as a unit behaving in its environment to obtain carriers from which it obtains "charges" that are complementary to its internal excitation state. We can

call "complementation" the process by which cancelation of an excitation state takes place. Charges may be carried by objects for consumption, by gestures, words, signs or symbols depending on the category of drives to which they apply.

Next we require an acceptable version of identified principles that seem to underlie and limit behavior and which should replace or supplement the analogies to laws of physics. The version of four basic principles presented here is based in the earlier work reported in reference[48] and has empirical support in the observations analyzed later in this paper.

The first principle is the need for a reserve of energies: metabolic-economic. For any individual organism to subsist, man included, it has to preserve a positive level of metabolic energy. Metabolic energy is transformable to economic energy and vice versa. The positivity requirement extends to economic "energy," credit included. These two kinds of energies obey conservation laws and can be transformed into each other. Carriers of complementary charges, including carriers of energy are acquired in exchange for "energy." Very little metabolic energy is used up in the actual drive complementation, but a lot is required in catching and transforming carriers. This principle is a particularization of the more general principle that survival of a living organism requires the values of essential variables to stay within certain limits.

The second principle needed is adaptation inertia and flexibility. Individuals, institutions and, in general, social and cultural setups in stable environments show no change but are capable, in greater or lesser degree, to appropriate change in response to cyclic or directional environmental change. Long term changes in organism arise from mutations affecting the genetic code that controls protein synthesis. If the change is advantageous for survival of the organism in his environment, the carrier has a better chance of passing it to his offspring which in turn will inherit the advantage. The change in institutional setups arise from new ideas, a sort of cultural mutation; it is not "genetically" transmitted; it spreads through learning and imitation.

The third principle is generalized "natural" selection which operates above individual organisms or institutions or other purposive groups of individuals and, in general, on social and cultural setups. This principle acts through the interaction of the components of these generalized individuals with corresponding features of their environments under the impulse of individual and collective drives. Setups which are efficient in their environments tend to be perpetuated while less efficient ones are progressively eliminated and substituted.

Living things have a propensity to accumulate at propitious points and to become themselves the basis for presence of other organism that prey or

parasite on them. This leads to a fourth principle which can be called mass accumulation and deaccumulation. A physical substratum and organisms living from it constitute carriers of complements for subsistence of other organisms and, thus, organisms of different orders accumulate in successive layers, provided the basic layer has a sustaining capacity, a carrier mass, above a minimum level. A layer that drifts below this minimum collapses carrying along all layers above it. On the other hand, an accumulation that increases to a certain size may provide conditions for the appearance of the first element of a new layer, a new order of predator or parasite that did not exist before at this point and which now can feed on the lower level mass accessible from it.

This principle seems to hold also at various levels: the accumulation of knowledge by one individual may reach a level where a flash of insight may create a new synthesis of previously disconnected thoughts. An idea may be rapidly propagated if there is a sufficient number of receptive individuals in which it takes root and develops, otherwise, it is quickly extinguished. Similarly, the accumulation of individuals in a similar emotional state may create conditions which are necessary but not sufficient for mob behavior. The mass accumulated is a necessary but not sufficient condition. We may thus say that mass accumulations show lower and upper critical levels. The upper is a threshold for new orders of phenomena, organisms or events to occur. The lower for the rapid disappearance of the existing accumulation.

These statements of principles do not, of course, capture the complexity of the real processes but for our purpose of providing a unified frame of reference and for guiding the formulation of testable hypotheses, they may retain sufficiently the essential features of group and personal behavior and of their inherent limitations needed to construct useful abstract models.

We need now a test of whether this sketchy model of man and the broad principles stated are useful for derivation of testable hypotheses about real man's behavior in an urban environment. We postulated the existence of a complementary relationship between needs of people and features of the environment. Man's environment is mostly self-organized and we should find this complementarity reflected in relationships between measures linked to individual or group drives, needs and desires, and measures of their environmental complements.

We cannot directly observe, much less measure, the excitation state of the reticular-thalamic-cortical complexes in people's brains. We have to infer motivation by judgement educated by whatever relevant knowledge we have of variables that can be observed and are related to actions we presuppose correspond to stable, persistent, motivational, states.

In our technologically conditioned urban environment, drives are

satisfied through acquisition or maintenance of complements for which money, a collectively accepted symbol of energy, must be given in exchange. To get money one needs to carry charges complementary to someone else's drives; for instance a mechanic carries with himself certain skills useful to someone needing or desiring to make tools. Tool-making becomes the mechanics way of obtaining food and other necessities. In addition his job acts, or should act, as carrier of complements for other individual needs which developed incidentally to the obtainment of food because of their adaptive advantage for survival long before man become urban. Examples of these are the need for participation in group tasks, the need to exercise skills, and the craving for feeling able and recognized as such. Work is the contemporary functional equivalent of hunting and food-gathering now fragmented and specialized into minute tasks performed by individuals according to inclination and acquired skills. The possibility of complementation depends now on these individual abilities and on the existence in the environment of drives or needs or others having these abilities as complements. Whenever charges of the one or the other exist, there is a possibility of complementation.

The complementary relationships between work and worker, in particular these of affiliations to a group, participation in group tasks and recognition and features of the job setting are difficult to study. We lack variables which are reasonably easy to observe. We therefore have chosen another very important set of drives, those associated with shelter, care protection, and socialization of offspring. In our urbanized life, these require as complements the use of dwellings and the access to services such as food distribution points, schools, and transportation.

Complementary carriers are brought into proper space-time positions for complementation by transportation systems. The frequency and magnitude of these movements depend on the space distribution of complementary carriers that, as long as the relevant charges are not completely purified from their physical carriers for transportation or transmission, must be brought to the proper *place* at the proper *time* for complementation to be possible.

The space distribution of these points, the separation between points offering similar services, depend on the local action of the mass accumulation principle. If the number of households is thinly spread, distances between points of similar services tend to be larger than in higher density places. The distances at which households find services are in part consequences of the mass accumulations principle.[53,54]

Census Bureau and other accessible sources give household and community data tabulated by single variables; for instance, households tabulated by income ranges or by size, or by education, etc., which obscure the

households real life multi-dimensionality. It is jointly the composition, ages and achievements of a household as a whole which determine its needs, its aspirations and its capacity to satisfy them. It is the set of joint characteristics of dwelling, neighborhood and transportation possibilities that determines whether these match or not the household's conception of its needs, desires, and economic capacity.

To study household relations of complementarity in residential choices involving dwelling, access to services and access to work, we need measurements on both households and areas on scales defined to capture, at least in part, this complementarity in its multidimensionality. The scales must be such that similarities among households in drives, capacities and constraints can be recognized and used to form groups and to assign, on the basis of adequate measurements, a household, or a dwelling-neighborhood-journey to work description to the group most similar to it.

We obtained this kind of observations through a small survey designed to detect and measure in the collected data the complementary characteristics of households of various occupations on one side and of their dwellings, neighborhoods and modes of transportation to work on the other. Details of design and analysis are given in reference 55.

Sample and Choice of Variables

We quota-sampled 469 employees from the work force of a Manhattan office organization by matching employee identification numbers with computer randomly-generated numbers. The quotas were assigned with the expectation of obtaining a minimum of 40 responses from each occupation. Questionnaires and instructions were delivered at the place of work, replies were anonymous. 167 usable questionnaire replies were obtained. Response by occupation was:

Engineers and other professionals:	78%
Administrative employees:	42%
Executive level employees:	42%
Clerical employees:	20%
Maintenance employees:	12%
Overall response:	34%

The questionnaire included the 16 household and 24 dwelling, neighborhood and transportation characteristics given in Table 1, the motivational questions in Tables 5 and 6 and other items not treated in this paper. Its length probably contributed to the low response of the maintenance and clerical workers.

The pairwise correlations indicated that from variables closely correlated,

some could be eliminated without much information loss and with corresponding gain in scarce degrees of freedom. To make this elimination less arbitrary, we questioned whether a variable could be derived from others likely to influence its magnitude and we retained the ones higher up on the line of causality. For instance: income level is probably directly determined by level of education, number of subordinates at work (scope of responsibility) and age, while the reverse causality is very unlikely. Income was therefore eliminated for subsequent analysis and the others retained. Among household variables, five were deemed likely to be at the causal end of others. These were: 1) number of earners, 2) number of non-earners, 3) number of students, 4) age of the household head and 5) number of years married. Five additional variables were deemed important in characterizing groups or useful in explaining eventual differences in residential preferences. These were: 6) years of schooling of household head, 11) number of work subordinates of household head, 12) number of errors in filling the survey questionnaire (indicative of verbal interpretation skills), 13) frequency of attendance at theater, opera and concerts, and 14) frequency of attendance at conferences and visits to the museums.

The various occupational groups seem to have characteristic values in variables 1 through 6, suggesting that in general households can be represented in a six-dimensional phase space with dimensions of household composition, age, and education. The other variables can be taken to represent properties of regions of this space.

Some qualitative characteristics of dwellings, neighborhoods and transportation are difficult to quantify unidimensionally and require use of several variables. For instance, to show clearly the differences between detached houses and apartments dwellings have to be characterized simultaneously by construction density (measured as the ratio of covered to ground space) by separation from nearest building and by size of ground plot.

In contrast to household causation in the area variables go from household and group needs to area characteristics mediated by public policies on zoning, taxation, service specification, etc. and by market reactions; there is not among our area descriptors a clearly recognizable set of causation variables. Causality arguments are not so clear for use in elimination of variables. We therefore more or less arbitrarily chose some variables and eliminated others with which their correlations were very high.

Of the 24 area variables observed the first nine (such as age of building, number of rooms, size of plot, density of covered space) characterize the dwelling, its immediate surroundings, separation from other buildings and provisions for pedestrian and vehicular traffic adjacent to it. Of these we

Table 1. Means and Standard Deviations

		Professionals		Administrators		Executives		Clerks		Labor	
		Means	Std. Dev.	Means	Std. Dev.	Means	Std. Dev.	Means	Std. Dev.	Means	Std. Dev.
	Household Variables										
1	Earners (#)	1.24	0.43	1.50	0.76	1.33	0.66	1.39	0.57	1.65	0.61
2	Non-earners (#)	1.16	1.03	1.19	1.12	0.95	0.65	0.50	0.75	1.06	1.03
3	Students (#)	0.88	1.13	0.88	1.43	1.62	1.25	0.18	0.48	1.00	0.87
4	Age of Household's Head (years)	37.88	10.06	40.28	12.89	49.97	6.84	39.29	13.70	42.82	11.89
5	Years Married (#)	8.86	7.52	11.81	10.89	21.90	7.40	10.46	13.17	15.94	11.98
6	Schooling (years)	16.35	2.34	15.72	3.26	16.23	2.07	12.07	2.28	11.29	1.99
+7	Prospective Schooling (years)*	16.75	16.94	18.34	21.75	16.79	18.17	2.43	5.46	11.00	11.98
+8	Total Income (th. $)	13.36	3.97	13.88	4.63	26.69	8.04	8.13	3.30	10.27	3.69
+9	Years in Dwelling (#)	6.18	7.30	9.09	9.80	11.33	8.75	5.14	5.25	8.00	7.10
+10	Years Familiar with Area Before Last Move (#)	2.22	5.76	3.66	6.91	4.10	8.45	2.43	6.15	3.06	4.08
11	Subordinates (#)	4.31	7.29	11.59	30.99	148.31	284.20	1.43	5.73	2.71	5.27
12	Area Data Errors and Ommissions (#)	1.73	2.06	2.09	1.77	1.82	2.61	5.50	3.91	2.82	2.58
13	Opera-Concert Attendances (#/mo.)	2.72	5.27	2.10	4.00	3.00	4.4	1.10	1.63	0.17	0.73
14	Museum-Conference Attendances (#/mo.)	1.18	1.66	0.56	1.50	1.73	2.53	0.51	1.42	0.17	0.73
+15	Outdoor Sports and Recreation (#/mo.)	8.06	17.52	11.67	9.21	10.53	17.32	2.54	4.66	5.35	12.51
	Dwelling, Neighborhood and Journey to Work Variables										
1	Building's Age (years)	20.98	17.17	25.94	26.34	20.51	16.68	31.96	20.34	22.24	19.92
2	No. of Rooms (units)	5.75	2.59	5.94	2.23	7.54	2.23	4.25	1.78	4.94	1.30
3	Rent or Cost/mo. ($)	140.92	39.55	130.41	52.01	213.10	102.24	100.79	23.70	105.41	40.26

+4	Covered Space Density	3.53	5.02	1.85	2.22	1.93	4.73	4.88	4.93	4.03	4.98
5	Sidewalk Width (feet)	6.61	5.22	7.25	17.21	3.79	3.78	8.39	5.17	6.88	4.31
+6	Minimum Building Separation (yards)	16.08	32.13	26.16	70.89	31.54	61.88	9.07	20.12	31.82	74.71
+7	Dist. to Shops (standard blocks)**	4.62	4.73	6.29	6.64	7.60	5.48	3.78	3.79	7.13	13.75
8	Dist. to Supermarket "	4.92	5.59	7.57	6.87	8.17	5.79	5.88	12.76	6.70	13.63
9	Dist. to Public Grade Sch. "	4.82	3.41	4.58	3.50	4.96	3.62	4.07	2.78	5.67	7.50
+10	Dist. to Public Jr. H. S. "	7.80	6.86	11.80	12.31	10.80	8.28	10.48	13.62	10.42	7.14
11	Dist. to Public High Sch. "	10.77	8.65	13.10	13.81	14.14	9.28	9.59	12.17	10.69	7.58
12	Dist. to Public Park "	11.95	19.77	13.45	14.60	16.52	17.16	8.11	7.64	5.94	7.79
13	Dist. to Small Plant "	12.61	9.80	15.59	16.26	14.85	9.00	10.37	15.09	11.01	11.69
14	Dist. to Large Plant "	22.55	18.00	25.13	13.79	27.08	22.00	12.10	10.37	20.75	26.10
+15	Dist. to Train Station "	10.55	10.90	11.45	9.95	14.23	15.35	10.99	16.33	14.91	25.76
+16	Dist. to Sway. Station "	88.51	117.11	95.17	96.50	102.24	91.31	23.45	54.56	76.34	135.44
17	Dist. to Bus Stop "	3.18	4.00	3.17	4.52	5.53	8.02	2.53	3.22	7.42	16.25
18	Total Riding Time (min.)	47.12	26.93	49.25	20.68	51.33	18.53	39.04	18.90	46.71	42.77
19	Total Transfer Time (min.)	12.67	9.06	16.00	9.51	13.21	8.65	10.64	5.49	11.06	7.64
20	Total Transfers (number)	1.57	1.02	1.56	0.95	1.62	1.09	1.57	0.88	1.06	0.66
21	Total Round Trip Cost (cents)	112.90	96.48	140.63	84.93	171.13	98.49	65.96	60.50	73.76	79.47
+22	Access Lanes (number)	4.04	2.42	2.84	1.14	3.77	2.54	3.50	1.48	3.29	2.49
+23	Ornamentation (0-1 indicator)	0.71	0.46	0.94	0.25	0.95	0.22	0.50	0.51	0.71	0.47
24	Size of Private Plot (th. sq. ft.)	5.68	7.95	9.30	15.23	17.08	21.64	1.06	2.39	3.39	5.71
	Sample Sizes	51		32		39		28		17	

* Total school years in prospect for the household (children and adults).

** Standard block: 212 yards, average of small sample from N. Y. City.
All distances given in blocks were assumed to be in standard blocks.

\+ Eliminated variable

retained for analysis the plot size, age of building, number of rooms, rent or cost per month and sidewalk width, which likely retain most of the information in the original set.

Of the distances to neighborhood shops, supermarkets, outdoor recreation and schools, quantities related to the mass accumulations in the neighborhood, we retain for analysis distances to supermarkets, public grade schools, public high schools and industrial plants. The latter are potentially offensive or detrimental to health and thus are likely to induce avoidance.

Of the next six variables, distances to public transportation, and descriptors of the household head's journey to work, distances to nearest subway and to nearest train station are eliminated.

In Table 1 the variables eliminated from the latter part of the study are marked with a cross.

The null hypothesis that occupational group mean vectors in the selected household variables are equal is rejected at $p = .001$. The corresponding hypothesis for the area vectors is also rejected at the same level.

Household and area variables were defined and chosen on presumption of their complementary relationships and we thus expect that if these relationships systematically obtain in the population they will show strongly in the sample. The presumption is essentially that points in the household space and their corresponding points in the dwelling-neighborhood-transportation space are on one hand indicators of active drives and on the other representation of their complements. Their positions in their respective spaces should thus exhibit mutually systematic variations. It should be possible to construct two simple functions, one in each space, that would be the best predictor of the other. Variations within each sample are indicative of the differences in the drives among individuals. We presume that these are representative of variations in drives likely to occur for any individual if his own circumstances changed. We assume that these functions are linear and use the technique of canonical correlation for their construction.[56] The magnitude and significance of the canonical correlation in each subsample would indicate how well variations correspond in both spaces. The normalized coefficients of the functions indicate the magnitude of the contributions to the canonical correlation by each component variable. The estimation of the coefficients in the functions proceeds from the product and cross product moment correlations in the two sets of variables. For detailed description of the technique, tests and computation programs the reader should refer to references 57, 58 or 59. Since it is impractical to include the complete tables in this paper, some significant moment correlations between pairs of variables were selected to illustrate

relationships between household characteristics, their reflection on dwelling neighborhood-transportation variables and the relationship between these last variables themselves.

The evolved relational structure of the city, as manifested in some of its physical dimensions, appears in the signs and magnitudes of these correlations. The differences in correlations among occupational groups show apparent value differences. For instance: higher number of earners in all groups, except clerks, are associated with the smaller number of non-earners (children of pre-school ages, dependent parents, etc.). There is no association between number of earners and number of students in any group. Household income is strongly associated with number of earners in the households of clerks and labor; this association is progressively less in the other household groups.

The number of students and the age of the household head are significantly correlated among professionals (the youngest group) and among executives (the eldest group). The correlations are positive and negative respectively and reflect the increase of number of children in school and then their departure from the household.

In the table (Household - Area), we observe that the correlations between number of non-earners and rooms in the dwelling is significant though low in the pooled sample but in the groups obtains only among professionals and executives. In contrast, the correlation between the number of students and the number of rooms in the dwelling is high in all groups and in the pooled sample, thus indicating that the needs for space are determined more by the number of children in school than by the number of pre-school children or dependent adults.

The number of rooms and density of construction is negatively and significantly correlated in all groups except labor. The number of rooms is similarly correlated with the size of the plot, except for labor and executives. The number of rooms and dwelling rent are not significantly correlated in the samples of clerks, labor and professionals. Apparently other factors influence their rents more strongly than dwelling size.

In general, the correlations show that households with more students obtain dwellings with more rooms and larger plots, lower construction densities, and higher rents requiring more time and expense in the journey to work. The larger dwellings are also located farther away from markets, shops and schools.

Distances to various types of services reflect the influence of need for accumulation of supporting masses: The higher the density of construction the shorter are the distances to shops, markets and schools. However, some of these distances are not so related within the labor and clerk groups, presumably because of their low economic capacity.

Table 2. Selected Moment Correlations

Pair	*Clerks*	*Labor*	*Professional*	*Administrators*	*Executives*	*Pooled*
1. *Household Variables*						
1 2		.57	−.40	−.40	−.70	−.42
1 8	.83	.72	.32	.50	.40	.23
2 8		−.47				
3 4			.41		−.71	.18
3 5			.72		−.43	.29
3 6		−.44	−.29			
8 13			.28			.23
2. *Household and Area Variables*						
2 2			.32		.34	.28
2 4			−.45			−.29
2 18	.36		−.28		.56	.25
3 2	.56	.61	.68	.72	.44	.65
3 4			−.40	−.31		−.30
3 8	.75		.42	.38		.30
3 11	.88		.33			.30
3 18	.38	.52	.32			.32
2 20	.63	.55				
5 4			−.52	−.35		−.25
5 21			.45			.19
7 4		−.49	−.43			−.30
7 11						.21
7 18	.42				.43	.22
7 24		.49		.38		.28
8 2			.32	.46		.48
8 3	.46	.42			.36	.60
8 8						
8 24						.43
3. *Area Variables*						
1 3	−.50	−.52				−.22
2 3				.58	.61	.51
2 4	−.34		−.57	−.57	−.32	−.46
2 7	.38		.30		.33	.26
2 8	.56					.27
2 16	.58		.37	.43		.38
2 18	.73		.36		.39	.37
2 21	.60		.42	.50		.50

Table 2. (Continued)

Pair	*Clerks*	*Labor*	*Professional*	*Administrators*	*Executives*	*Pooled*
3. *Area Variables* Continued						
2 24	.78		.47	.38		.42
3 24			.41		.39	.45
5 18	−.48	−.51	−.66		−.45	−.34
5 21	−.40	−.53	−.64			−.34
7 8		.98	.79	.86	.82	.71
8 9		.93	.35		.45	.40
8 11	.88	.48	.43	.74	.46	.60
8 13	.90	.47	.54	.43	.42	.58
15 17	.60	.86	.29			.52
18 21	.56	.71	.70	.34	.60	.58
Levels						
.05	.37	.48	.28	.34	.32	.15
.01	.48	.61	.36	.44	.41	.20
.001	.59	.73	.45	.55	.51	.25

Some general flaws consequent to current practices in urban design are clearly shown by the correlations of dwelling, neighborhood, and transportation variables: The greater the distance to the point of access to one form of public transportation, the greater are the distances to all others. The greater the density of construction, the number of traffic lanes and, presumably, the levels of activity, the lesser are the between building spaces that can speed up diffusion of air pollutants.

In general, the measurements proposed here describe household and area relational structures, and cross relationships well.

Canonical Correlation Analysis

The canonical correlations are all extemely high indicating a very close correspondence between the two spaces of description. The reliability of the association in the clerical group is, however, low; the number of observations in its sample is too small.

Among professionals the number of years married and the number of rooms are the two variables whose concommitant variations in the household respectively area spaces contribute most to the canonical correlation. The corresponding pair for administrators is number of students and size of plot, for executives number of non-earners and riding

time in journey to work. For clerks, in sharp contrast with the others, frequency of visits to museums and conferences and cost of round trip to work.

In general the pattern of concommitant variations in the sample from professionals suggests that outdoor and indoor space needs increase with the number of years since the formation of the household, independently and in addition to other increases because of age of household head, number of students and increased ease from economic restraint. Economic ease appears as a product of increased professional standing and responsibility, which permits the occupation of larger dwellings (more rooms and larger plots) at higher rents, farther from small industrial plants and requiring more transfer time, more transfers and longer riding times. The number of non-earners and the education of household head contribute in minor degree to the correlation. Professionals living in higher density areas may participate more frequently in cultural activities than those residing in more outlying places as shown by the systematic variation of the measures of participation. As we shall see, convenient access to cultural activities does not in general seem to be a factor in choice of dwellings. Cost of journey to work and distances to bus stops show no direct contribution to the association.

In the sample of administrators the concurrent variations suggest a similar increase in demands for space but with stronger influence from number of students than in the case of professionals. The lack of concurrent variation in number of earners, schooling of household head, age of building, dwelling rent or cost, sidewalk width, distances to supermarkets and grade schools and journey to work variables, which do not contribute to the relationship, show relative homogeneity of this group in these aspects of the household and in their general type of preferred residential areas.

Table 1 shows that executives prefer larger dwellings located farther from densely populated areas than those of other groups. Total riding time is the strongest contributor to the canonical relationships between household and residential area characteristics. Cost or rent has some influence but less than for professionals. Although this group has the largest households, the lower correlation between number of students and rooms in the dwelling and the stronger relationship with number of non-earners suggest that its space demands are in excess of the minimal needs or acceptance standards of the two groups. Small children are probably more likely to get own rooms than in the other groups.

The clerical group is different from the others in that its household heads are predominantly female. In its sample, the direction of systematic variation indicates that household cultural interest is concurrent with

Table 3. Canonical Correlations and Vectors

	Professionals	*Administrators*	*Executives*	*Clerks*	*Pooled*
Maximum Canonical Correlation	.93	.98	.93	.99	.79
χ^2 (126)	209.4	177.3	170.2	215.9	317.3
Significance Level	<.0001	<.005	<.005	<.0001	<.0001
Household Variables					
No. of Earners	.1531	.0610	.0540	.1163	.0562
No. of Non-earners	−.0801	−.1551	*−.4766*	.1062	*.3324*
No. of Students	*−.4284*	*−.7777*	*−.3998*	*.2505*	*.7502*
Age of Household Head	*.3437*	*−.3423*	*.4297*	.1296	.0816
No. of Years Married	*−.7303*	*.2600*	*−.4173*	−.1497	*.3556*
Schooling	−.1810	.0680	−.1024	.1007	*.3173*
No. of Subordinates	*−.2240*	*.2948*	*.2482*	*−.5554*	*.2508*
No. of Area Data Errors & Omissions	.0441	*−.2411*	−.0823	−.0445	−.0194
No. of Opera & Concert Attendances	.0575	.1413	*−.3929*	*−.2724*	.1044
No. of Museum & Conference Attendances	*.2165*	.1143	.1343	*.6926*	−.1249
Area Variables					
Private Ground Space	*−.4858*	*.4725*	.1989	*.5043*	.1166
Building's Age	.1465	−.0393	.0725	−.1520	−.0203
No. of Rooms	*−.6187*	*−.2688*	*−.3221*	*.3110*	*.9062*
Rent or Cost/mo.	*.3320*	−.0648	*−.2034*	.0798	.1814
Sidewalk Width	−.1495	−.0101	.0443	*.2312*	−.0792
Distance to Supermarket	.1116	−.0001	.0084	.1590	.0869
Distance to Public Grade School	−.0362	.0573	.0172	.1374	.0408
Distance to Public High School	−.1703	*.4487*	−.1894	.1162	.0930
Distance to Small Plant	*−.2845*	*−.3283*	.1528	*−.4268*	.0058
Distance to Large Plant	.0397	*.4432*	−.0475	.1914	−.0122
Distance to Bus Stop	.0388	*−.4255*	*.3643*	.1236	−.1002
Total Riding Time	.1420	−.0235	*−.7800*	−.0783	.1118
Total Transfer Time	*−.2186*	.0463	.0637	.0132	*.2014*
Total Transfers	.1798	.0114	.0297	.1063	−.1635
Total Round Trip Cost	−.0169	.0768	.0147	*−.5067*	−.1332

number of subordinates, an indicator of standing and income, and with number of students. These variations are concurrent with variation in round trip cost of journey to work, size of plot, number of rooms, distance to industrial plants, age of building and in minor degree other variables. A plausible interpretation is that with increased subordinates (implying also

increased household income), there is tendency to move away from the location of industrial plants (i.e., unattractive parts of central city) in response to space needs, thus increasing correspondingly the journey to work cost, the journey time, transfers or time lost transferring.

The number of observations in the sample from the labor group was insufficient for a canonical correlations analysis. The complementary relationships between households and environment in this group are shown in the significantly correlated variables that suggest casual connections.

The following are the percentages of variance ($r^2 \times 100$) of some area variables which can be attributed to significantly correlated household variables: (correlation signs in parenthesis)

	% Variance Attributed	
Number of rooms to number of students	37%	(+)
Size of private plot to number of subordinates	58	(+)
Sidewalk width to number of students	30	(-)
Sidewalk width to number of subordinates	18	(-)
Rent or cost to number of years married	23	(-)
Rent or cost to total income	17	(+)
Rent or cost to years occupancy	33	(-)
Distance to supermarkets to number of subordinates	83	(+)
Distance to public junior high school to number of subordinates	38	(+)
Distance to public grade school to number of subordinates	80	(+)
Distance to public high school to number of subordinates	26	(+)
Distance to small plant to schooling of household head	21	(+)
Distance to small plant to number of subordinates	25	(+)
Distance to bus stop to number of subordinates	78	(+)
Total riding time to work to number of subordinates	67	(+)
Total riding time to work to number of students	27	(+)
Total transfer time to work to number of students	29	(+)
Total transfer time to work to years married	26	(+)
Total transfers to number of students	30	(+)
Total transfers to age of household head	33	(+)
Total transfers to years married	30	(+)
Total round trip cost to number of non-earners	21	(+)
Total round trip cost to number of subordinates	48	(+)

Canonical Correlation in the Pooled Sample

Although the pooled sample is not representative of the unstratified population (the group samples were not weighted by group proportion of the total), the canonical correlation analysis of the pooled relationships between the household and area variables adds some information and its inclusion thus seems worthwhile.

Two functions appeared significant at better than the .0001 level with correlations of .79 and .60 respectively, thus indicating two orthogonal directions in which the household and area variables represent the same household in their respective spaces. Table 4 presents the household and area variable coefficients corresponding to the second root.

In the function corresponding to the maximal root the household variable having the strongest influence in the correlation is the number of students in the household. The variable having the strongest influence from the dwelling-neighborhood side is the number of rooms; with a magnitude of .90 it indicates that by itself alone it could have accounted for almost all of the correlated value. Among other variables of some influence, we find schooling of the household head and the number of its work subordinates, to a great extent the determinants of household income. Some variables which appeared important in the group correlations show practically no influence when considered over the pooled sample. On the area side total transfer time and the other journey to work variables show some influence in the value of the function. Rent or cost per month and size of plot have minor influence. The variables distance to market, schools and industrial activities are of negligible weight.

In the direction corresponding to the second root the household variables of strongest influence were the number of subordinates of the household head, other determinants of household income, and some of the indicators of household needs. On the dwelling-neighborhood side in contrast with the first root, we find rent or cost per month as the most important variable in determining the value of the correlated function. Neither size of plot nor journey to work variables, except total riding time, show appreciable influence. Of minor importance, appears distance to small plant, building age and building separation, which are indicative of nearness to points of intense activity.

The two directions of systematic variation thus suggest the existence of two spread clusters showing different indicators of which and when household needs become active and can be satisfied and which form the needs and constraints take in the dwelling-neighborhood variables. For the first cluster these needs are expressed in demands for inside space in the dwelling. Cost is secondary. In the other cluster rent or cost is of primary

Table 4. Vector (Coefficients) From Second Root - Pooled Sample

	Canonical Correlation	.60	
	χ^2 (104)	168.59	
	Significance Level	<.0001	
Household Variables	*Coefficients*	*Area Variables*	*Coefficients*
1 No. of Earners	.1577	24 Size of Private Plot	−.0874
2 No. of Non-earners	*.2202*	1 Building's Age	−.1228
3 No. of Students	*.2996*	2 No. of Rooms	*.4301*
4 Age of Household's Head	*−.4150*	3 Rent or Cost/mo.	*−.8204*
5 No. of Years Married	*.4624*	5 Sidewalk Width	−.0487
6 Schooling	*−.2092*	6 Building Separation	−.1166
13 No. of Subordinates	*−.6005*	9 Distance to Public Grade School	.0117
14 No. of Area Data Errors & Omissions	−.0594	10 Distance to Public Jr. High School	.0683
15 No. of Opera-Concert Attendances	−.1826	13 Distance to Small Plant	.1772
16 Museum-Conference Attendances	−.0990	14 Distance to Large Plant	−.0220
		17 Distance to Bus Stop	.0190
		18 Total Riding Time	*.2391*
		19 Total Transfer Time	−.0595
		20 Total Transfers	.0640
		21 Total Round Trip Cost	.0360

importance. Space comes second. The ranking analysis helps to identify the first as mainly composed of households from the professionals, administrative and executive groups. The second as the groups of clerks and labor with contributions from the youngest segment of the other groups.

Ranking of Motives for Moving and Selecting Dwellings

The ranking of motives for moving from a residence and selecting a new one shows that out of a list of 29 reasons to leave a dwelling most persons indicated one, the average number selected was three, few indicated more than four, none more than eight, as relevant to their decision. For the selection of new dwelling the most frequent number of considerations for choice was five, the average was four and few indicated more than six out of 16. This could be another instance of Miller's Magic number seven plus or minus two.[60] The decision to move requires much less information than the choice of dwelling. The total number of information categories is constrained by human capacities.

Insufficient dwelling space was the weightest reason to move from a dwelling, in all groups. Right size was the weightest reason for the choice of the new one among executives, professionals and administrators. Clerks and labor had right cost as the first consideration for accepting the new

place. The rank of home ownership in the professional and administrator sample, second highest after size, suggest that the move was to own home. That explains the larger number of considerations for choice. Among executives the reversal in rank between home ownership and increase in family size suggests move from an owned dwelling to another, a larger one, as a more frequent reason for the change. Increases in family size were not a frequent motive for change of dwelling among households of clerks. Instead, neighborhood deterioration and deterioration of building were the next weightest ranking reasons that made households move. Safety of neighborhood is a higher consideration in these two groups for the choice of new dwelling. Security apparently was not so much up in the minds of executives for their last move.

The five samples show that in the selection of new dwellings the importance of amenities varies with the standing and, presumably, the income of the households; it is lowest among clerks, highest among executives.

Changes in life cycle stage, such as marriage, have importance corresponding to the likely frequency of its occurrence in the group; moving because of marriage ranks equally among clerks and professionals, the youngest groups, is lowest among the administrators, the middle group, and increases in the executive group perhaps because of higher frequency of second marriages.

Dissatisfaction with transportation is not a reason that by itself goads people to change dwelling but it is a consideration of varying importance to the various groups for the selection of a new one. Nearness to work place was third in importance to professionals but not so much for any of the other groups. Convenience to public transportation was important for clerks but in all the other groups transportation in general takes its place after many other considerations. Convenience to cultural activities had no influence in either motivation to leave a dwelling or choosing a new one.

In general, the ranking of expressed motives for the last move and choice of new dwelling agree with the canonical and correlation analysis. The drives active in the move appear clearly in the explicit needs and constraints operating on the household. The compromises arrived at are reflected in the characteristics and service implications of the chosen dwellings and neighborhoods.

Statistical Differentiation Between Occupational Groups

The canonical correlation analysis of household and area characteristics show that substantial differences exist between groups of households from different occupations. However, a qualitative stratification by occupation is

Table 5. Reasons for Last Move

A	Reasons	Professionals			Administrators			Executives			Clerks			Labor		
		Weight	Rank	F*	Weight	Rank	F*	Weight	Rank	F*	Weight	Rank	F*	Weight	Rank	F*
12	Living Quarters Were Too Small	.233	1	16	.241	1	11	.270	1	11	.168	1	3	.174	1	3
14	Wanted To Own Instead of Rent	.114	2	6	.185	2	–	.112	3	6	.076	5	1	.028	8	1
3	Family Size Increased	.106	3	8	.110	3	6	.148	2	5	.021	11		.103	4	1
5	Got Married	.095	4	7	.046	8	1	.062	5	2	.126	4	2	.028	8	1
1	Income Increased	.068	5		.059	4		.062	5	1	.025	10		.028	8	
10	Deterioration of Neighborhood	.052	6	1	.056	5	4	.062	5	2	.160	2		.146	2	5
19	Lack of Yard	.050	7	1	.046	8	2	.075	4	3	.034	9		.056	6	1
21	Too Far From Work	.041	8	1	.013	13	1	.005	14		.025	10			–	
15	Transportation Uncomfortable	.037	9	2	.008	14		.038	8	1	.042	8	2		–	
18	Too Much Street Traffic	.032	10			–		.016	10	1		–		.080	5	1
7	Family Head Changed Work Place	.023	11	1	.032	9		.047	6	1		–			–	
13	Living Quarters Were Too Large	.018	12	1		–		.010	12			–			–	
25	Too Far From Outdoor Recreation	.018	12		.013	13		.010	12	1		–		.014	10	

9	Increase In Rent Or Taxes	.018	12	2		–		.016	10	1	.046	7	1	.019	9	
28	Poor Schools	.018	12	2		–		.008	13	1		–		.078	8	1
4	Family Size Decreased	.014	13	1		–			–			–		.052	7	
17	Transportation Inconvenient	.013	14	1	.029	10	1	.013	11	1	.055	6	1		–	
29	Wanted to Rent Instead	.013	14			–			–		.017	12			–	
6	Separated From Spouse	.010	15	1		–			–			–		.056	6	
22	Too Far From Schools	.010	15			–			–			–		.019	9	
24	Too Far From Shopping	.006	16		.026	11			–			–		.019	9	
26	Too Far From Friends Or Relatives	.005	17		.048	7	3	.003	15		.025	10		.019	9	
11	Deterioration of Building	.003	18		.051	6	2	.023	9	2	.134	3	3	.127	3	4
27	Too Far From House of Worship	.002	19			–			–			–			–	
8	Work Location Changed For Another Member	0				–			–			–			–	
2	Income Decreased	0			.008	14	1		–		.025	10			–	
16	Transportation Costly	0			.008	14			–			–			–	
20	Lack of Garden	0			.019	12	1	.036	7	2	.017	12			–	
23	Too Far From Theatres, Etc.	0				–			–			–			–	

Column A: Order in Questionnaire
Column F*: Times indicated sufficient to move

Table 6. Reasons for Choice of New Dwelling

		Professionals		*Administrators*		*Executives*		*Clerks*		*Labor*	
A	*Reasons*	*Weight*	*Rank*	*Weight*	*Rank*	*Weight*	*Rank*	*Weight*	*Rank*	*Weight*	*Rank*
15	Right Size	.166	1	.193	1	.183	1	.130	3	.130	3
13	Right Rent or Cost	.154	2	.125	2	.103	4	.187	1	.193	1
5	Near Work Place	.074	3	.041	8	.057	7	.036	9	.042	8
8	Neighborhood View	.070	4	.113	3	.142	2	.036	9	.042	8
3	Safe Neighborhood	.067	5	.071	5	.046	9	.138	2	.097	4
4	Good Public Schools	.061	6	.100	4	.140	3	0	15	.143	2
14	Near Train Station	.060	7	.057	6	.072	5	.047	8	. 0	13
1	Near Outdoors Recreation	.056	8	.033	10	.033	11	.021	12	0	13
2	Near Suburban Shopping	.052	9	.039	9	.036	10	.034	10	.029	10
9	Safe Open Play Space	.049	10	.055	7	.070	6	.013	13	.063	7
16	Right Down Payment	.048	11	.016	12	.008	13	.023	11	. .025	11
11	Near Bus Stop	.041	12	.033	10	.049	8	.070	6	.038	9
7	Near City Shopping	.031	13	.023	11	.003	14	.086	5	.025	11
2	Near Subway Stop	.028	14	.016	12	.011	12	.110	4	.076	6
6	Near Theatres, etc.	.023	15	.012	13	.002	15	.010	14	.013	12
10	Near Relatives and Friends	.019	16	.057	6	.049	8	.055	7	.084	5

Column A: Order in Questionnaire

somewhat arbitrary, and we prefer to detect the differences between groups quantitatively in the household and area characteristics and to identify which of the variables are most useful to ascertain these differences.

Here this is done by applying the technique of linear discriminant analysis to the data from the five groups. The technique consists essentially of finding directions for projecting multi-dimensional sample points orthogonally into a space of less dimensions in such a way that the variation between the projected samples on this space is as large as possible relative to the variation within the sample.

The technique finds the transformation of the original observations into a new system of coordinates such that the measure of separation among group samples is maximized with respect to the measure of within group scatter. That is, the transformation is such that the ratio of among-group sum of squares to the within group sum of squares is maximum. For detailed description of this technique the reader is referred to references 57, 58, and 59.

Let

$$\lambda = \frac{v' A v}{v' W v}$$

where λ = the discriminant criterion

A = the among-group sum of squares matrix for the original variables

W = the within-group sum of squares matrix for the original variables

v = the vector of coefficients of the transformation

λ is determined from the solution to equation, obtained by differentiation

$$(A - \lambda W)\, v = \theta$$

$$(W^{-1} A - \lambda I)\, v = \theta$$

choosing for λ the maximum root of the characteristic equation

$$|W^{-1} A - \lambda I| = 0$$

Since we have 5 groups, there are at most 4 non-zero characteristic roots λ_i of this equation and corresponding to each a characteristic vector v_i formed by the coefficients of one discriminant function. The matrix associated with the transformation is the matrix formed by the characteristic vectors as columns:

$$v = (v_{iu}) \quad \begin{matrix} i = 1, \ldots, n \\ u = 1, \ldots, 4 \end{matrix}$$

where $n = 10$ for the household variables

$n = 15$ for the area variables

Discriminants for Household Groups

The solution to the characteristic equation yields 4 non-zero roots of $W^{-1}A$ and 4 corresponding characteristics vectors that exhaust the discrimination power of the ten household variables. The total discrimination power of the variables is given by the trace of $W^{-1}A$. The contribution of each discriminant vector (the vector associated with each non-zero characteristic root) is indicated by the percentage that its characteristic root is of the total. The statistical significance of dispersion along each discriminant vector can be evaluated by use of Rao's χ^2 approximation to a test of dimensionality. Table 7 gives the trace of $W^{-1}A$, characteristic roots, cumulative percentage, degrees of freedom, level of significance of each discriminant function significant above .05, normalized and scaled discriminant vectors. The vectors are scaled by multiplying corresponding elements of the normalized vector with diagonal elements of W to show the relative contribution of the within group dispersion in each variable. Table 8 shows the transformed group means and standard deviations.

The coefficients of the normalized vectors are the cosines of the angle formed by the discriminant vector with the respective axis. Thus the coefficient of -.79 of education indicates that this is the direction of the axis to which the direction of the discriminant vector is closest. Education is the single variable having the strongest influence in the separation between the groups as is also indicated by its weight in the scaled vector. The second closest direction to the discriminant vector is that of number of students, third and fourth were those of number of errors and omissions and number of earners. However, the second variable in order of importance in the separation was age of household head.

Corresponding to the second root, which accounts for 16% of the discriminant power, we find the discriminant vector very near to the direction of earners, that is, to participation of the household in the labor market. Other variables of influence are the number of subordinates of the household head, the number of non-earners and the number of students. The scaled variables show that the strongest influence in the discrimination are the number of years married and the number of subordinates.

The vector corresponding to the third root, which accounts for 11.66% of the power of discrimination, also lies close to the direction of labor force participation but in a different quadrant. The discriminant vector is also inclined in the direction of number of earners and the number of nonearners. If we exclude the variable area data errors and omissions, we find that education of the household's head and the variables that define household life cycle stages; no. of earners, no. of students, age of the household head and no. of years married are the most important

Table 7. Household Discriminant Vectors

Characteristic Roots of $W^{-1}A$		1.1786		.3767	.1812	
Degrees of Freedom		13		11	9	
χ^2		191.2		61.6	29.2	
Significance Level		<.0001		<.0001	<.001	
Vectors	*Normalized*	*Scaled*	*Normalized*	*Scaled*	*Normalized*	*Scaled*
No. of Earners	*.20*	1.50	*.86*	6.55	*.80*	-6.12
No. of Non-Earners	-.04	-0.46	*-.30*	-3.55	*-.54*	-6.42
No. of Students	*-.48*	-6.84	*.20*	2.82	*-.20*	-2.84
Age of Household Head	-.08	*-10.77*	.01	1.91	-.01	-1.61
No. of Years Married	-.06	-7.76	.15	*18.17*	.01	1.20
Schooling	*-.79*	*-24.46*	*-.31*	-9.66	.08	2.56
No. of Subordinates	-.00	-3.25	.01	*18.53*	.00	1.53
No. of Area Data Errors & Omissions	*.32*	*10.54*	.14	4.49	.12	4.11
No. of Opera & Concert Attendances	-.01	-4.77	-.01	-5.82	.00	0.31
No. of Museum & Conference Attendances	-.02	-4.60	-.00	-0.92	.01	3.16
Trace: 1.771 Percent of Trace		66.45		15.99		11.66

Table 8. Means and Standard Deviation in Household Discriminant Space

	Professionals		*Administrators*		*Executives*		*Clerks*		*Labor*	
	Mean	*Std. D.*	*Mean*	*Std. D.*	*Mean*	*Std. D.*	*Mean*	*Std. D.*	*Mean*	*Std. D.*
Vector 1	-16.51	2.56	-16.05	2.75	-18.86	2.33	-11.47	2.01	-12.54	1.86
Vector 2	-2.45	1.85	-1.35	2.54	1.42	3.24	0.02	2.85	1.08	2.67
Vector 3	-0.40	0.70	-0.72	0.67	-0.32	0.70	-0.02	0.91	-1.13	0.73

differentiators between groups. Hence a simple model of man's essential characteristics and principles that regulate its behavior leads to the suggestion that the natural grouping of households is by life cycle stages and education.

The occupational groups overlap considerably in the reduced space as can be seen in Table 8 of means and standard deviation; classification by education and life cycle stage could yield a set of groups where the motivational relationships between household characteristics and their dwelling, neighborhood and journey to work choices may emerge with increased clarity.

Differentiation Between Group Dwelling-Neighborhoods-Journey to Work

The analysis yields four non-zero roots of $W^{-1}A$ for the area variables. Table 9 shows the roots, degrees of freedom, approximation to χ^2 significance levels, vectors and discriminant power for the two discriminant functions which are significant above or at the 5% level.

The first vector, which accounts for over 66% of the discriminant power, lies very close to the direction of number of transfers; its cosine with it is near 1. It is also somewhat inclined in the direction of number of rooms. The variables of strongest influence in this discriminant are dwelling rent or cost/month, round trip cost, total number of transfers, total transfer time and distance to supermarket. This indicates that the function contrasts large low density and small higher density dwellings. The second discriminant function, which accounts for 16% of the discriminant power, lies also very close to the transfers axis but in a different quadrant. It is also somewhat inclined towards number of rooms and a bit towards transfer time and almost completely orthogonal to all other area variables. The most important variables in this vector were total transfer time and total number of transfers. This suggests the direction of intermediate to high densities within the city but in its outlying boroughs. Table 10 shows the means and standard deviations of area variables in the reduced two-dimensional space. The group mean show that professionals and administrators, and clerks and labor are very close in the first vector. The executive group is fairly different. The groups overlap considerably in both vectors. The homogeneity in the dwelling-neighborhood-transportation variables could perhaps be improved by separation into distinct types starting from household life cycle and education groups. The statistical differences between groups in area characteristics may be almost entirely due to the different proportions of households in different life cycle stages in the samples and to differences in education, economic and sex related constraints among occupational groups.

Summary and Conclusions

We started with the need to substitute in urban and transportation process modeling the over-simplistic conception of urban man as a material particle moving under fields of forces for a more accurate, but simplified, version based on his motivational mechanism. From the accumulated knowledge of the disciplines that study live organisms, we extracted some principles that obtain in the relationships between organism and environment and which must necessarily obtain also for man. The most

Table 9. Area Discriminant Vectors

Characteristic Roots of $W^{-1}A$	0.6468	0.1555		
Degrees of Freedom	18	16		
χ^2 Approximation	105.3	25.9		
Significance Level	<.0001	= .05		
Vectors	*Normalized*	*Scaled*	*Normalized*	*Scaled*
Private Ground Space	0.05	8.27	0.00	−0.75
Building's Age	−0.01	−1.80	−0.02	−4.32
No. of Rooms	*0.28*	7.92	*0.21*	5.98
Rent or Cost/mo.	0.04	*33.53*	−0.01	−5.84
Sidewalk Width	−0.00	−0.48	0.01	1.07
Distance to Supermarket	−0.01	*−11.89*	−0.01	−5.98
Distance to Public Grade School	−0.01	−2.95	0.01	4.03
Distance to Public High School	0.01	8.84	0.00	2.18
Distance to Small Plant	−0.00	−0.44	0.00	0.14
Distance to Large Plant	0.00	5.75	0.00	4.44
Distance to Bus Stop	−0.00	−3.85	0.00	3.77
Total Riding Time	−0.02	−6.04	−0.01	−1.91
Total Transfer Time	−0.10	*−11.02*	0.11	*11.30*
Total Transfers	*0.95*	*11.79*	*−0.97*	*−12.03*
Total Round Trip Cost	0.02	*20.05*	0.00	0.09
Trace: .9735	Percent of Trace	66.45		15.98

Table 10. Means and Standard Deviations in Area Discriminant Space

	Professionals		*Administrators*		*Executives*		*Clerks*		*Labor*	
	Mean	*Std. D.*	*Mean*	*Std. D.*	*Mean*	*Std. D*	*Mean*	*Std. D.*	*Mean*	*Std. D.*
Vector 1	9.40	3.02	9.17	3.49	14.40	5.73	6.09	2.02	6.03	2.22
Vector 2	0.23	0.90	0.52	1.14	0.05	0.77	−0.47	0.91	0.74	0.93

fundamental of these relationships being one of complementarity between the motive drives of the organisms and some elements in the environment which yield for the organism the things etc. that satisfy the drive. We then selected a set of drives particularly important for urban man, those of dwelling selection with respect to place of work, defined measurements on households and dwelling-environment and tried to establish the existence of complementarity and the relative importance of characteristics contributing to its measure. For the measure of complementarity we selected Hotellings canonical correlation. In addition to measurements or indication of

household and area characteristics we collected explicit statements of the motives for leaving a dwelling and for selecting a new one in the last move made by the sampled households.

The samples showed consistently a high measure of complementarity between the indicators of household needs and their satisfactors. The analysis brought forward the limitations experienced by different groups, the similarity of drives, the diversity of preoccupations and, to some extent, the change in dominant preoccupations from security for self, to certain amounts of space and to other amenities as freedom from constraints increased.

It is therefore possible to quantify household-dwelling-neighborhood characteristics with respect to the drives active in residential choice and with respect to constraints endogenous to the household or which depend on the exogenous forces contributing to giving the urban area its form. There are simple measurements whose dimensional relationships imply a neighborhood convenience and attraction to different types of households. Several measurements of this or similar type should be further investigated and some selected as parameters for city design on grounds of close association to promotion of formal and informal community functions, to promotion of diversity and contribution to attractiveness, repulsion, satisfaction or dissatisfaction of people with various forms of public spaces and neighborhood designs.

The analysis of simple correlations between pairs of household variables and between pairs of dwelling-neighborhood journey to work variables shows how changes in the needs and resources of household imply changes in the characteristics of the dwellings and how the evolved structure of neighborhoods and transportation is necessarily reflected in the behavior of households. For example, an increase in family size represents an increase in the amount of dwelling space needed by a household. If the household cannot afford that increase at its current dwelling density, or desires the change, it can increase space only by moving to a lower density location which immediately implies increases in distances to points of household services, to points of access to all public transportation and increased time, transfers and cost in journey to work. These increases in distance result from the increase in serviced territory that must be made in the location of service enterprises to accumulate the critical mass required for their support or, as in the case of public schools and other services, to justify their existence.

The ranking of motives for last moves and choices of new dwellings show explicitly the desires and constraints predominant in each group. The main motives in the ranking concur with the inferences made from the canonical correlation analysis. Living space, home ownership, change in life

cycle, removal of economic restraints, neighborhood view, convenience to transportation to work area, with some difference in rank order, are of predominant importance among professional, administrators and executives. In the clerical and labor groups considerations of neighborhood safety and of rent become stronger than in the other groups. The strongest motive for the last move was in all the groups the need for larger living quarters. The economic constraints operating in the clerical and labor groups makes right rent or cost the highest ranking reason for choice of new dwelling, ahead of safety of neighborhood which was in second place among the predominantly female clerical group, and ahead of good public schools which was second for the labor group.

The intensity of these explicit motives and constraints are quantitatively reflected in the magnitude of the coefficients of the canonical correlation functions. For instance, the variable number of students did appear less important in the canonical household function of the professional group than in the corresponding function of the administrative group. The administrative group is, on the average, older than the professional group, and has a higher frequency of households with children in school. Also the average age of household heads is older in the administrative group and their incomes likely to be higher and thus economically less constrained than the younger professionals. The coefficient for rent has correspondingly higher weight in the professional group, little for administrators and clerks. It has considerable weight for executives but here we find that the coefficients of dwellings and neighborhood variables indicate a stronger influence of transportation to very low density locations and are somewhat less closely associated to family space needs than those of the other groups.

The pull of convenience to centers of cultural activity, shopping, supermarkets, services and transportation appears very weak. This accords with a hierarchical ordering of drives; some, like these associated with high cultural interests, become active in general only when more worldly needs, such as the needs for space and safety, are fully satisfied. The clerical group ranking of safety of neighborhood much higher than professionals, administrators and executives cannot be interpreted to indicate that these groups value it less. It shows that persons in the clerical and labor groups are more frequently aware of or exposed to risks than members of the other groups. The fact that they report deterioration of the neighborhood as the second most important motive in the decision to move indicates that poor conditions are more frequently met in their environment than in that of the other groups. The ranking is what could be expected from the existence of adaptation levels;[61] individuals get used to a level of particular stimulus or preoccupation and tend to increase their awareness or sensitivity to departures from it in some relationship to the magnitude of

the departure. This behavior extends to a wide range of stimuli, and we can see its manifestation in the rank differences of motives in different groups. Perhaps this is the reason why transportation does not appear so important among either the reasons to leave a dwelling or select a new one; it seems taken for granted at a level of adaptation to cost, inconvenience, noise, time lost, etc. Avoidance behavior occurs when conditions depart from the adaptation level in excess of some threshold or reach magnitudes that threaten the life or integrity of the person.

The results suggest also some plausible household objectives and standards. The almost unanimous ranking of size of living quarters as the main motive for leaving the last dwelling and accepting the current one suggest, for instance, that the number of rooms occupied per person by household of each group is indicative of the possibility of developing general standards of room sizes and number of rooms per person that would adequately meet household space needs for our sample in general.

The relationship between household and dwelling neighborhood characteristics in the executive group not only suggests that dwelling characteristics are somewhat in excess of middle group family standards, but also shows a preference for very low density dwellings associated with longer riding times, higher cost and more time lost transferring in the journey to work than those of the other groups. Furthermore, the neighborhood characteristics indicated that in general the dwellings of this group are farthest away from shopping, supermarkets, cultural and recreational centers and from high schools and points of access to all forms of public transportation. This shows, apparently in direct contradiction with Zipf principle of minimization of effort, basic to the theories of behavior used in transportation planning such as the gravity and opportunity theories, that the households having the greatest freedom of choice select dwellings which are farthest away from the regular destinations for their most frequent travel. The same tendency is observed in the other groups in association with relaxed economic and psychological constraints although related more closely to household indicators of indoor and outdoor space needs.

The very high ranking of desire for home ownership in established households, the preoccupation with safety of neighborhood and dwelling, and the indication that demand for space may continue to grow, as economic and time constraints decrease, at the expense of convenience to activities and services deemed attractive, suggests that the underlying motivation respond more to deeply rooted emotional factors than to reasoned evaluation. The observations seem to fit well the ethological interpretation[62] of a drive for individual and family territory strong enough to overcome the attraction of cultural and other facilities that

satisfy lower ranking or intermittently occurring drives, and which can be satisfied thanks to the existence of the automobile. If this is so, the deterioration of the urban environment blamed on the car and the real estate developers push, resulting in the inordinate growth of surburbia, would follow naturally from inborn drives at the removal by the automobile of distance deterrences and from the subsequent growth of sufficient masses to support essential service activities at increasing distances from city centers. The amorphousness and ugliness of this growth is likely due to lack of strong shaping forces substituting for the now weakened restraints that gave earlier cities their form.

If, to the inborn impulse to secure a minimum amount of space, is added the associated impulse to avoid the anxieties and annoyances of competition in overlapping territories, the territorial ambiguity resulting from space rental rather than ownership, the accelerating drift of rentals toward higher values and space designs that present large uninterrupted reflecting surfaces rather than enclosing, retaining ones, one wonders why the resulting centrifugal propensity acts rather slowly to disintegrate what remains of the central city. The implications are that a necessary condition to reverse these trends is to find an economically viable technology that allows the satisfaction of these inborn drives in more compact city forms. The design of urban spaces adequate for the expression of other drives that by themselves could not overcome the need for a minimum amount of individual space could be used to somewhat reduce the space amounts demanded but not to the seemingly unrealistic current levels. This technology seems to be now at hand.[64]

We noted that the variables associated with the larger coefficients on the household side of the canonical correlation functions are often the ones that correspond to coordinates of a phase space in which households could be mathematically represented. Several of these variables also appeared in the discriminant analysis as important differentiators between groups. Furthermore, the data shows that certain combinations of values in these variables are associated with life stages of households. Dwelling and neighborhood characteristics seemingly reflect the life cycle stages predominant in the household clusters. Thus, there is a very strong suggestion that homogeneity of groups for further analysis should be based on life cycle stage characteristic values in these variables. Analysis by life cycle stage rather than by occupational grouping may further clarify the relationship between household and area characteristics and the impact these carry on some of the observed household behavior.

Multiple discriminant analysis appears promising for the definition of groups of households statistically homogeneous. Its combination with experimental design techniques seems promising for introducing limited

control experiments in urban transportation and social studies. Approaches similar to the one suggested here, with appropriate definition of behavior unit, environment and complementary variables seem useful for scientific study of incidence of poor health (physical and mental), of social dissociation, criminality, etc. and their relations to factors in the interfaces individual-family environment, family-community, community-society.

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